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THE COMMONWEALTH OF SCIENCE

IN 1660, 281 years ago, in an essay on the usefulness of natural history, Robert Boyle, the English philosopher and scientist, who, in addition to his contributions to physics, studied the chemistry of combustion and respiration, wrote these prophetic words - "he, that thoroughly understands the nature of ferments and fermentations, shall probably be much better able than he, that ignores them, to give a fair account of divers phaenomena of several diseases (as well fevers as others) which will perhaps be never thoroughly understood, without an insight into the doctrine of fermentation:". Almost two centuries elapsed before Boyle's prophecy was fulfilled and its implications realized in 1857 by the studies of Pasteur on microbial fermentation. With all the important work Boyle accomplished in physics his name is associated especially with the founding of chemistry as a separate science. He was primarily a chemist; so too was Pasteur. Furthermore, both men viewed their experimental work from the physiological standpoint. Indeed, Boyle is said actually to have carried on experiments in physiology - a field, however, in which his biographers tell us he was hampered by "the tenderness of his nature" and his consequent dislike of anatomical dissection. Pasteur, a chemist by training, realized full well the physiological import of his studies in fermentation and constantly insisted that the chemical activities of microorganisms were but the expression of physiological processes adapted to promote some vital need or purpose. It i

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therefore no mere accident that microbiology from its very inception became intimately linked with chemistry, physiology and medicine.

As Boyle foresaw, it was indeed the insight into the nature of fermentation that enabled Pasteur to give "a fair account" of several diseases; that such diverse diseases as those of silkworms, chicken cholera and rabies in man and animals are due to living infectious agents as specific in behavior as the microbial agents of fermentation are selective in the type of chemical change they induce.

It is not my purpose to review the historical developments of bacteriology or the rapid succession of discoveries that followed the announcement of the nature of fermentation and the germ theory of disease - with these you are all familiar. Nor shall I dwell upon the brilliant achievements of those pioneers in bacteriolog whose explorations in the field of infection and immunity disclosed the basic principles that underlie modern advances in the medical, agricultural and soil sciences. But I cannot refrain from reiterating and again emphasizing the interdependence and common interests of these specialized fields; the reciprocal benefits and mutual enrichments that have accrued from the early and increasingly fruitful union of microbiology with chemistry, physiology and medicine.

Our membership, constantly growing in numbers, comprises groups of individuals highly specialized and primarily interested in one or another of the several aspects of bacteriology. There is a natural preoccupation with the subject matter of one's own field; a tendency, perhaps less justified, for each of us to regard his own corner of knowledge as the source and directive of all biological thought. Now I am not indicting microbiologists alone and certainly not any particular group within our organization. In proof of the fact that such tendencies are common to all sciences may I recall the words of the president of one of the great foundations which distribute funds for scientific research - "Choose off the shelves a group of learned treatises and sample the prefaces: Mathematics: - it is the queen of sciences; Physics: . it is the source of the basic laws for the behavior of all matter; Chemistry: a recent text says, 'Chemistry touches all human interests. It is the central science; Biology: - it assaults the greatest mystery of all, the mystery of life; Astronomy: - it has the cosmos and eternity for its heroic theme: Philosophy: - it is an examination of the ultimate questions which give life meaning. And so one could expand the list, with brave and startling claims for the central character and basic importance of one field, one speciality, one segment of knowledge after another."

It is perhaps just as well that there was no copy of a learned treatise on microbiology on his book shelf that day or he might have added: Microbiology: - it is the king of sciences, it assaults the citadel of life's greatest mystery, He graciously says in explanation of these seemingly contradictory and exaggerated claims that "they arise partly because of the egocentric character of man, but they are also due to wholly selfless enthusiasms, to the concentration to which specialized competence naturally leads."

The moral is not far to seek and its application to our Society is perhaps not too remote. Despite man's egocentric nature, despite the wholly selfless enthusiasms and the concentration natural to specialized competence in any one field of bacteriology, let us not lose sight of the fact that the solidarity of this Society rests upon "the unity of its intellectual life and that life cannot, without disaster, be broken up into separate parts".

Study of the behavior of microorganisms has greatly aided in the formulation of principles that have given new thought and direction to biochemical investigation. Analyses of certain processes involved in the metabolism of unicellular microorganisms have materially helped in the elucidation of many problems relating to animal and plant physiology, and have added to the understanding of the part biocatalysts have in the chemical events and transformations in living tissue cells. Thus, from these related fields there is accumulating a significant and integrated body of facts which together constitute what is now referred to as "comparative biochemistry". This is further evidence of the growing recognition of the similarity, even the unity perhaps, of many of the principles that govern the cellular functions and chemical activities of diverse living things, from the lowest to the highest forms of life, from the miraculous microbe to man himself.

By way of illustration, may I cite one or two examples of the many ways in which microorganisms serve as highly sensitive reagents for unravelling many important biochemical problems in bacterial and animal physiology and nutrition.

Much of the knowledge concerning the intermediate metabolism of carbohydrate and its significance for the understanding of muscle physiology received initial impetus from the recognition of the nature of alcoholic fermentation by yeast. Knowledge of the exacting requirements of various species of microorganisms for vitamins, many of which form the prosthetic groups of vital enzyme systems, has led to development of biological methods of increasing specificity for determination of these essential substances in animal blood and tissues. The establishment of the complete identity of biotin, coenzyme R, and vitamin H was greatly facilitated, when, instead of the laborious, time consuming, and expensive method of rat assay it was found that this specific entity could be more readily and accurately determined by microbiological tests with Rhizobium and yeast cells. The identification and isolation from egg albumin of a substance called 'avidin', which is responsible for the so-called egg white injury of animals, was li ewise greatly aided by the use of microbiological techniques. For during the chemical procedures incident to the isolation of avidin its presence in any given fraction could be quantitively followed by observing the absence of bacterial growth in culture media to which the suspected material has been added; since avidin by combining with and rendering unavailable all free biotin in the medium deprives the bacterial cells of this essential metabolite and thus prevents their growth.

The isolation from soil bacilli of enzymes capable of specifically attacking creatinine has provided biologically specific techniques that have proved useful in the study of human metabolism.

With all due reverence Ithink I may preserve the intent of that proverb of Solomon in which he councils the sluggard to learn diligence by observing the ant, when I say to you microbiologists, to the physiologists and biochemists as well - "Go to the microbe, thou scientist, consider its ways and be wise."

During the latter half of the 19th century, it was established that plants utilize carbon dioxide for the synthesis of their cell materials, finding the energy required in photochemical reactions catalyzed by chlorophyl. Animal cells, on the other hand, were known to require complex organic carbon for the building up of their protoplasm, as well as for all their other biochemical reactions. Toward the end of the last century (1887) it was shown that, like plants, certain bacteria (the autotrophic group) can utilize carbon dioxide for synthetic processes finding their energy in the oxidation of simple inorganic compounds. On the contrary, heterotrophic bacteria, like animal cells, were believed to utilize only organic carbon. Within the past 6 years, however, it has been recognized that certain heterotrophic bacteria can incorporate carbon dioxide into more complex organic compounds; for example, forming succinic acid during the fermentation of glycerol in the presence of carbon dioxide. Furthermore, it has only recently been found that the animal organism has to a limited but definite degree the power to synthesize organic compounds from carbon dioxide - a power long supposed to be a peculiar prerogative of chlorophyl bearing plants. Investigators have injected bicarbonate containing radio active C into animals and from their livers have recovered glycogen containing the isotopic carbon. Moreover, it has also been shown by the use of isotopic carbon as a tracer, that liver tissue from pigeons can <u>in vitro</u> cause carbon dioxide to enter into organic combination to form ketoglutaric and amino acids. The first recognition of the utilization of carbon dioxide by heterotrophic bacteria and the recent finding of the participation of carbon dioxide in the carbohydrate cycle in animals indicate that the phenomenon is probably of universal occurrence. When taken together, these interlocking facts constitute a new and striking example of the chemical unity of life.

The strategy of warfare against infectious agents of disease lies not alone in discovery of ways and means of fortifying the natural and specific defenses of the host, - important as these are - but in a concerted effort to learn the vulnerable points of attack in the structural and cellular mechanisms by which these hostile agents invade and overcome the living tissues of man, animals and plants. The importance of the normal and immune reactions of the host I value not less in emphasizing more on this occasion, the significance of gaining depper insight into the mode of life, the aggression weapons and predatory ways of the infectious agent. In the light of present knowledge I venture to add to the prediction of the seventeenth century scientist: - that he who understands the nature of the host-parasite relationship shall probably be much better able, than he who ignores it, to give a more adequate account of divers phenomena of infectious diseases which will perhaps be never thoroughly understood without an insight into the life processes of the host and parasite.

In a recent report of the Rockefeller Foundation from which I freely quote, Mr. Raymond B. Fosdick in speaking of "Science and the Moral Order" expresses in these weighted words the spirit of man's search for truth; - "In spite of its claims and accomplishments science is today under sharp attack. The growing public realization that its powerful tools can be used for man's enslavement and destruction has given rise to bitter questions and charges; and we read today of civilization betrayed by science and of a degraded science that shirks the spiritual issues and hypnotizes its victims with its millions of gadgets.In this hour of intellectual confusion and moral chaos the social consequences of science, he continues, have been brought to the fore and the question is persistently asked: Are these consequences so important, because of technical applications, that the social interest is paramount over intellectual interest?

"The question arises" Mr. Fosdick points out," because science as a techninique for gaining understanding of nature is also a technique for gaining control over nature - that is, it is a technique for gaining power."

On my daily round to and from the laboratory I pass one of the city's modern High Schools; across its portal deep chiseled in granite are the words of Francis Bacon "Knowledge is power", and power, says President Fosdick, "can be used by evil men to do evil even more obviously and dramatically than it can be used by men of good will to do good."

"But this", he points out, "is true of many things in life - the sulphonamides one of the most beneficient developments of modern medical science came from the dye industry, but so did mustard gas" - and he might have added the Mendelian principles of heredity came from the monastery, but so did gun powder.

As he remarks, "Exactly the same principles of physics are employed to point a 500 ton telescope at a star and a 15 inch naval gun at its target. Language is a powerful tool which can be used to mirror spiritual insight or to spread false and destructive propaganda. The possibility of misuse is not an argument for no use at all." The charge that scientists disavow concern with social consequences arises from far too narrow a view of science. "For science is more than the technologies that cluster about it - more than its inventions and gadgets. It is even more than the discovery and correlation of new facts. Science is a method, a confidence and a faith. It is a method of controlled and rechecked observations and experiments objectively recorded with absolute honesty. It is a confidence that truth is discoverable. It is a faith that truth is worth discovering."

I am not here concerned with the philosophical arguments of whether or not pure science is of itself necessarily a moral force. Happily microbiology needs no defense of its intellectual aims or its social ends. They have never been accused of irresponsible indifference to social consequences. They have undeniably and always been in the service of human welfare.

But I am concerned with our moral obligations: - in this hour of national peril when our own country has been thrust into the most cruel and infamous war in history, we individually have loyally pledged our services in defense of country, liberty, and civilization. This is our obligation. But in these days when the threat of an intellectual blackout abroad has already darkened laboratories and universities hitherto beacons of knowledge, when by the mad spirit of conquest, scientists in subjugated countries have been exiled and scholarship enslaved by political ideology, we, as members of this scientific organization have another duty - an obligation to science. We need be gravely concerned about the future of science and its share in the world order that is yet to be.

Only 3 months ago, under the auspices of the British Association for the Advancement of Science, a group of distinguished scientists, including representatives from many differen tt countries met in war distracted London to consider the international relations of science and its part in world planning after the war. On that occasion the American Ambassador in addressing the conference stressed the significant fact that men of progressive minds,conscious of the common interests and aspirations of science, dared look beynnd the war to consider the reestablishment of science in the service of constructive civilization. It is the ancient tradition of the spirit of science that it follows no flag, recognizes no geographical boundaries, and sets up no trade barriers. Complete freedom of scientific thought, and the free interchange of knowledge are prerequisites for the survival of the spirit of inquiry. They are to the Commonwealth of Science what the Bill of Rights is to the life of democracy.

On that occasion Sir Richard Gregory, President of the British Association presented the following charter of science which was unanimously adopted by the Conference. Its seven articles represent not a creed but a policy, they possess no sanctity or finality, but they do represent the spirit of science.

DECLARATION OF SCIENTIFIC PRINCIPLES

1. Liberty to learn, opportunity to teach and power to understand are necessary for the extension of knowledge and we, as men of science, maintain that they cannot be sacrificed without degradation to human life.

2. Communities depend for their existence, their survival and advancement, on knowledge of themselves, and of the properties of things in the world around them.

3. All nations and all classes of society have contributed to the knowledge and utilization of natural resources, and to the understanding of the influence they exerwise on human development.

4. The service of science requires independence combined with cooperation and its structure is influenced by the progressive needs of humanity.

5. Men of science are among the trustees of each generation's inheritance of natural knowledge. They are bound, therefore, to foster and increase that heritage

by faithful guardianship and service to high ideals.

6. All groups of scientific workers are united in the Fellowship of the Commonwealth of Science which has the world for its province and the discovery of truth as its highest aim.

7. The pursuit of scientific inquiry demands complete intellectual freedom and unrestricted international exchange of knowledge; and it can only flourish through the unfettered development of civilized life.

I close with the very words with which Pasteur concluded his inaugural address at the founding of the Pasteur Institute in 1888:

"Two opposing laws seem to be now in control. The one, a law of blood and death opening out each day new modes of destruction, forces nations to be always ready for the battle. The other, a law of peace, work and health, whose only aim is to deliver man from the calamities which beset him. The one seeks violent conquests, the other the relief of mankind. The one places a single life above all victories, the other would sacrifice hundreds of thousands of lives to the ambition of a single individual. The law of which we are the instruments strives even through the carnage to cure the wounds due to the law of war. (Treatment by our antiseptic methods may preserve the lives of thousands of soldiers). Which of the two laws will prevail

God alone knows. But of this we may be sure, that science, in obeying the law of humanity, will always labor to enlarge the frontiers of knowledge."